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AN AERIAL RADIOLOGICAL SURVEY OF THE

WHITE OAK CREEK FLOODPLAIN OAK RIDGE RESERVATION

OAK RIDGE, TENNESSEE

DATE OF SURVEY: SEPTEMBER - OCTOBER 1986

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ABSTRACT

An aerial radiological survey was conducted over the White Oak Creek Floodplain of the Oak Ridge Reservation during the period 30 September through 3 October 1986. The survey was performed at the request of the United States Department of Energy (DOE), Oak Ridge Operations Office, by EG&G Energy Measurements, Inc. (EG&G/EM), a contractor of the DOE. The survey results will be utilized in support of the Remedial Action Program being conducted at the site by Martin Marietta Energy Systems, Inc., operator of the Oak Ridge National Laboratory (ORNL).

A flight line spacing of 37 meters (120 feet) and a survey altitude of 46 meters (150 feet) yielded the maximum data density and sensitivity achievable by the aerial system, which was greater than that achieved from prior surveys of the entire Oak Ridge Reservation. Isopleth maps of Cs-137, Co-60, and Tl-208 implied concentrations, and exposure rates provided an estimate of the location and magnitude of the man-made activity. These maps, overlaid on a current photograph of the area, combine to yield a view of the radiological condition of the White Oak Creek Floodplain.

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1.0 INTRODUCTION

An aerial radiological survey was conducted over the White Oak Creek Floodplain of the Oak Ridge Reservation during the period 30 September through 3 October 1986. The survey was performed at the request of the United States Department of Energy (DOE), Oak Ridge Operations Office, by EG&G Energy Measurements, Inc. (EG&G/EM), a contractor of the DOE. The survey results will be utilized in support of the Remedial Action Program being conducted at the site by Martin Marietta Energy Systems, Inc., operator of the Oak Ridge National Laboratory (ORNL).

The entire Oak Ridge Reservation has been surveyed three times in the past by EG&G/EM. The earlier surveys were conducted in 1973, 1974, and 1980.[1,2] The purpose of the present gamma survey was to perform a high geographic resolution and high sensitivity survey of the White Oak Creek Floodplain, a small portion of the Oak Ridge Reservation.

Aerial photographs of the site from 5762 meters (18,900 feet) above mean sea level (msl) were obtained on 22 September 1986 by EG&G/EM. This imagery serves as an underlying map for the gamma data in this report.

2.0 SURVEY AREA DESCRIPTION

White Oak Creek drains the southeast portion of Bethel Valley around the X-10 facility, a primary research and administrative complex on the Oak Ridge Reservation. The creek passes through Haw Ridge into Melton Valley, between Haw Ridge and Copper Ridge, and then flows into White Oak Lake before entering the Clinch River.

The portion of the White Oak Creek Floodplain which lies in Melton Valley was the primary survey area. Forty-eight flight lines, about 5 kilometers (3 miles) long and separated by 37 meters (120 feet), were flown in the valley. The flight lines followed the valley in a northeast-southwest direction, ending in the southwest on the west side of the Clinch River and in the northeast 120 meters (400 feet) short of the road to the Health Physics Research Reactor (HPRR).

Additional areas in Bethel Valley were also surveyed. These included White Oak Creek itself (about 2 kilometers in length) just south and adjacent to X-10, the north-south road beside the X-10 west fence line (about 900 meters), and the creek called West Tributary which extends 1300 meters in a westerly direction from X-10. Parallel flight lines were not flown in Bethel Valley, but rather several repeated passes were made over each of the creeks and the road.

3.0 SURVEY EQUIPMENT AND METHODS

3.1 Aircraft System

A Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter was used as the aerial platform (Figure 1). The aircraft carried two detector pods, one contained ten 5.1-cm thick × 12.7-cm diameter cylindrical sodium iodide (thallium-activated), NaI(Tl), detectors and the other contained nine detectors. One space in the second pod contained a 5.1-cm thick × 7.5-cm diameter NaI(Tl) detector shielded by a cylindrical lead shield with 2.5-cm thick walls. This detector was experimental and provided a higher spatial resolution than the others. Only the total count rate above 40 keV (no energy spectra) was recorded from the detector. In addition, the output from a single, unshielded 5.1-cm × 12.7-cm detector in the first pod was recorded separately from the other 18 detectors. This detector served to increase the dynamic range of the system.

Gamma signals originating in the NaI(Tl) detectors were routed to the Radiation and Environmental Data Acquisition and Recorder (REDAR IV) system for conversion and storage on magnetic tape. Pressure, temperature, and radar altitude transducer data were also acquired and stored by the REDAR. Real-time gamma energy spectra, total gamma count rates, and other data were output to a small CRT screen for the system operator.

FIGURE 1. *MBB BO-105 HELICOPTER SYSTEM*

The aircraft pilot was guided over the programmed flight lines by an indicator that derived its signal from the triangulation of two ultrahigh frequency (UHF) transponders on the ground and a master unit in the aircraft. One transponder was located on Chestnut Ridge, about 500 meters (1640 feet) north of X-10; the other transponder was located on the Experimental Gas Cooled Reactor (EGCR) building beside Melton Lake. These transponders provided positioning of the helicopter accurate to 3 to 15 meters (10 to 50 feet) depending on the relative placements of the transponders. The transponder position data were also stored by the REDAR.

3.2 Data Van

A minicomputer-based system (Figure 2) housed in a van was used during the survey to evaluate the aerial data immediately following each survey flight. The system contains hardware and software that operates on the survey data stored on magnetic tape. The system operator can plot both gamma energy spectra from any portion of the gamma survey and count rate isopleths scaled to a map or photograph. In this manner the isotope emitters, their intensity, and location can be identified.

3.3 Aerial Survey Method

A standardized procedure for aerial gamma surveys was followed during the survey of the White Oak Creek Floodplain. Steps in the procedure are as follows:

1. A perimeter survey of roads in the survey area was flown. The position data from the transponders were used to scale each subsequent gamma survey datum to its correct position on a map and an aerial photograph of the area.
2. A test line was located along Bethel Valley road, beginning 5 kilometers (3 miles) and ending 6 kilometers (4 miles) northeast of X-10. Repeated passes over this line were used to compare the system sensitivity from flight to flight. Passes at different altitudes over this line were used to check and obtain the effect of altitude for terrestrial background.
3. A water line over Melton Hill Lake was located. The water line yields the total airborne, aircraft, and cosmic contributions to the aerial gamma data. The average value of the water line data, before and after each flight, provides the background value used later in this report (Equations 2 and 3, Section 4.1).
4. Following the perimeter and initial test line and water line flight, routine survey flights began. Each flight—preceded by a preflight in which the system was calibrated and the data tape analyzed for proper system operation—consisted of:
   a. A pass over the test line and the water line at survey altitude.
   b. Passes in a NE-SW or SW-NE direction over the Melton Valley survey lines or over the creeks in Bethel Valley.
   c. A repeat pass over the water line and the test line.

   All the survey flights were flown at an altitude of 46 meters (150 feet). Appendix A lists the general survey parameters.

FIGURE 2. *DATA VAN*

After each survey flight the data were evaluated for integrity and anomalies in a routine manner on the computer-based data reduction system. All the gamma, position, and meteorological data were plotted and examined.

4.0 GENERAL DATA REDUCTION

Two primary methods are used to evaluate the gamma fluence measurements made with the aerial system's NaI(T*l*) detectors. The first is the gross count (GC) technique which is used to determine exposure rate. The second is the spectral window technique which is used to measure concentrations of specific nuclides. These and other methods are described in detail in a separate publication.[3]

4.1 Gross Count Rate

The gross count is defined as the integral count in the energy spectrum between 38 keV and 3026 keV.

$$GC = \sum_{38\ \mathrm{keV}}^{3026\ \mathrm{keV}} \text{Energy Spectrum} \tag{1}$$

This integral includes all the natural gammas from K-40, U-238, and Th-232 (the major terrestrial natural gamma emitters). Other natural contributors to this integral are cosmic rays, aircraft background, and airborne radon daughters.

The response versus altitude of the aerial system to terrestrial gammas has been measured over a documented test line near Las Vegas, Nevada for which the concentration values and the 1-meter exposure rates have been measured separately. With this calibration the terrestrial gross count rate measured from the air can be extrapolated to the 1-meter exposure rate in microroentgens per hour (μR/h) for natural radioactivity. The conversion equation is:

$$\underset{\text{Rate}}{\text{Exposure}}\ (1\ \mathrm{m}) = \left[[GC(A) - B]/1325\right] \mathrm{Exp}(0.001830 \times A)\ \mu\mathrm{R/h} \tag{2}$$

where

A = altitude in feet
$GC(A)$ = gross count rate at altitude A (cps)
B = cosmic, aircraft, and airborne radon background

The coefficient, 0.00183, was normalized to the mean temperature (24° C) and pressure (14.1 psi) during the Oak Ridge survey. This coefficient was also re-evaluated from the test line data as outlined in Section 3.3. The difference between the Nevada value and the Oak Ridge value was 1.5%.

Equation 2 was used to compute the exposure rate from the terrestrial gross count rate. For the Oak Ridge survey, flown at 46 meters, Equation 2 becomes:

$$\underset{\text{Rate}}{\text{Exposure}}\ (1\ \mathrm{m}) = (GC - B)/1000\ \mu\mathrm{R/h} \tag{3}$$

The gross count has been used for many years in the aerial system as a measure of exposure rate. Its simplicity yields a rapid assessment of the gamma environment.

Anomalous or non-natural gamma sources can often be found from increases in gross count rate over the natural count rates. However, subtle anomalies are difficult to find using the gross count rate in areas where its magnitude is variable due to, for example, geologic or ground cover changes. Differential energy data reduction methods, as discussed in the next section, are used to increase the aerial system's sensitivity to anomalous gamma emitters.

4.2 Spectral Windows

The aerial system produces each second a gamma energy spectrum from which the GC is computed. Generally, the ratio of natural components in any two integral sections (windows) of the energy spectrum will remain nearly constant in any given area:

$$\sum_{E=a}^{b} ES \Big/ \sum_{E=c}^{d} ES = \text{Constant} = K \tag{4}$$

where

ES = energy spectrum
E = energy
$d > c > b > a$

In practice, the value of K (Equation 4) is obtained from a background portion of the survey area and the test line which are chosen for the absence of man-made isotopes. Then Equation 4, in another form, is evaluated from the spectra obtained over the survey area:

$$S = \sum_{E=a}^{b} (ES) - K \times \sum_{E=c}^{d} (ES)\ \text{cps} \tag{5}$$

where

S = The net count rate (or signal) from anomalous gamma rays

The signal, S, will vary around zero and become significantly positive in the presence of anomalous gamma rays whose primary (or uncollided) energy lies between a and b. The variance of S was measured over background areas or computed from the energy window count rates. The signal, S, was chosen to be significant when it was greater than 4σ (4 times the standard deviation of S for background areas). Count rates were generally large enough so that σ could be computed from normal statistics.

5.0 RESULTS

The results of the various data reduction procedures are presented as isopleth (i.e., constant count rate) contour maps superimposed on an aerial photograph of the White Oak Creek Floodplain area.

The contour intervals are labeled with consecutive letters of the alphabet starting with "A" as the lowest value. A conversion scale on each figure relates the letter label to exposure rate or isotopic concentration. It is important to note that it is the intervals and not the contour lines that are labeled.

The overall accuracy of the results vary strongly with the spatial extent of the source on the ground. This is due to the large area averaged by the airborne detector. Values are correct to within a factor of two in areas where the source is uniformly distributed over an area that is large compared to the detector's field-of-view. However, the aerial system underestimates the magnitude of spatially small sources of radiation. For example, a source 5 meters (16 feet) in diameter would require a correction factor of 200.

The placement of the isopleths is quite accurate particularly where the gradient is large. Centers of anomalous regions are correctly located to within 15 meters (50 feet). However, in areas exhibiting little variation, e.g., nearly uniform, placement may be incorrect by considerably more. Some isopleth contours are placed some distance from the actual source due to the large area averaging. This is most noticeable over water where the shoreline is yet in the detector's field-of-view.

5.1 Exposure Rate Isopleth Map

The exposure rate isopleth or contour map, Figure 3, is composed of two parts: (1) the isopleths over the Melton Valley, and (2) the letter plots over the creeks in Bethel Valley. No attempt was made to contour the Bethel Valley creek areas because single lines do not provide sufficient data.

The exposure rate is inferred at 1 meter above the ground from the total gamma count rate (30 to 3026 keV) at 46 meters (150 feet). The conversion equation from 46 meters to 1 meter is given in Section 4.1, Equation 2. This is a conversion developed for natural isotopes uniformly distributed in the soil over large areas (several hectares) and approximates exposure rates due to the natural isotopes plus other man-made isotopes found in this area.

Exposure rates on the map vary from a minimum of 0 to 3.5 μR/h over the Clinch River to greater than 2600 μR/h at 28,000 NE, 17,500 NW. (The coordinate system is taken from the S-16A map produced by the Tennessee Valley Authority (TVA) in June 1974. This map is also known as the Administrative Grid System.) The predominate background level is C (5.3 to 8.0 μR/h). There are many active areas on the map indicated by small closed contours at exposure rate levels greater than background. These are areas where man-made isotopes are concentrated. The Cs-137, Co-60, and Tl-208 located in these areas will be discussed more fully in the following sections.

It is important to note that the aircraft system tends to extend the length and width of the exposure rate contours over those that would be measured on the ground. The aircraft system has a more unobstructed view, in general, of a source than does an instrument at the surface. In addition, the exposure rate directly over radioactive sources of finite size (<400 meters in diameter) is expected to be smaller when measured by the aircraft system than when measured at the 1-meter level. Since the extent of the source is not known, the conversion from aircraft to ground is for a large-area source greater than 400 meters in diameter. Table 1 lists several correction factors to be applied to exposure rates over finite area sources on the contour map.

5.2 Cesium-137 Concentration Isopleth Map

The Cs-137 isopleth map, Figure 4, shows activity in nearly the same areas as does the exposure rate

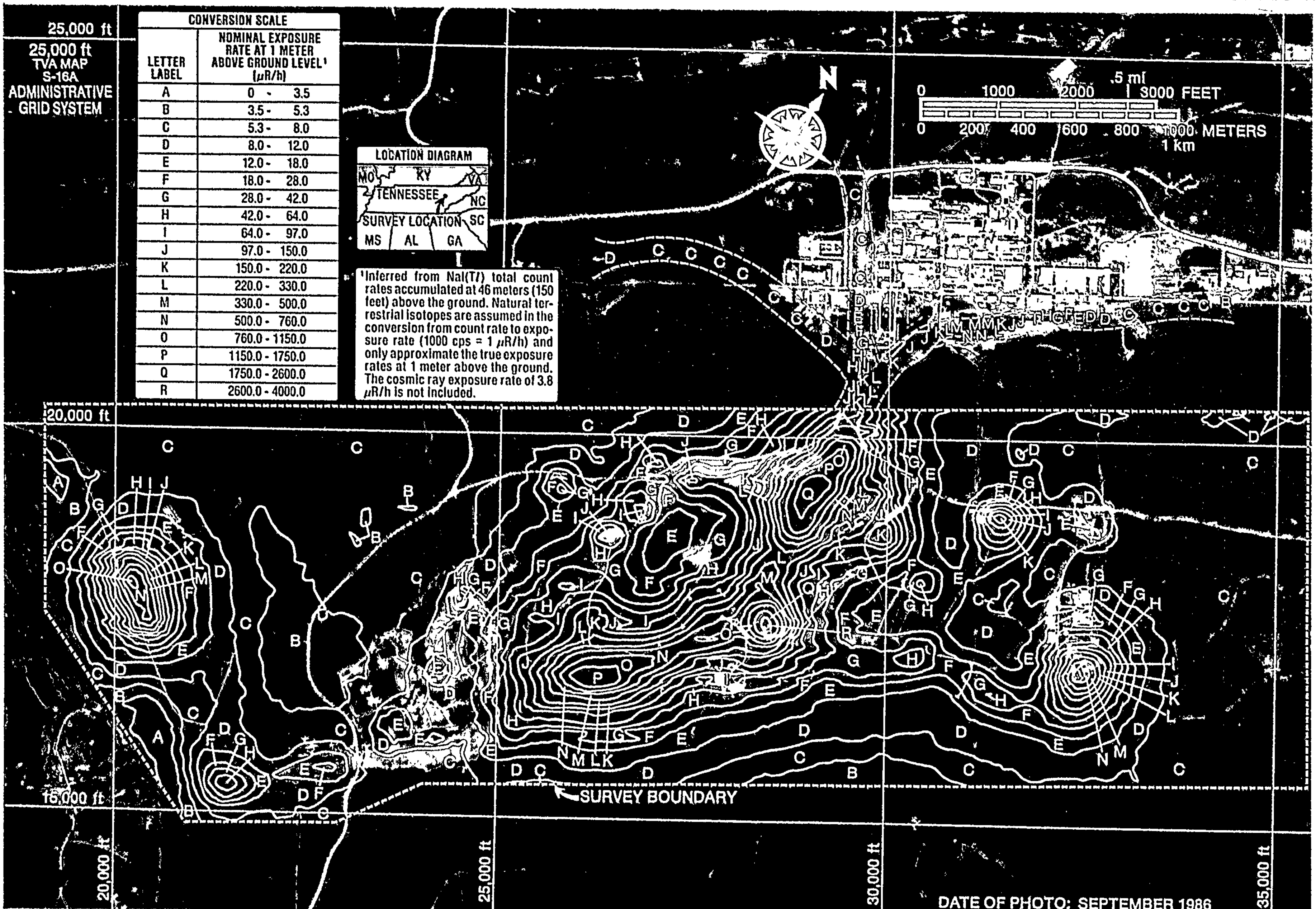

FIGURE 3. *TERRESTRIAL GAMMA EXPOSURE RATES DERIVED FROM THE SEPTEMBER-OCTOBER 1986 SURVEY OF THE WHITE OAK CREEK FLOODPLAIN, OAK RIDGE RESERVATION*

Table 1. Exposure Rate Correction Factors Versus Source Spatial Extent	
Diameter of Source (meters)	Correction Factor[a]
20	30.0
50	6.5
100	2.2
200	1.2
400	<1.1

[a]The exposure rate over the center of a finite diameter source should be multiplied by the correction factor for the exposure rate map in this report.

map except for the High Flux Isotope Reactor at 32,500 NE, 17,500 NW. The aerial system does not reveal Cs-137 in the latter area. Also, the locations of exposure rate maxima and minima correlate well with the Cs-137 photopeak count rate maxima and minima.

The Cs-137 isopleth map represents the count rate in the 662-keV photopeak as measured by 20 5.1-cm thick × 12.7-cm diameter cylindrical NaI(*Tl*) detectors at 46 meters altitude. Conversions from photopeak counts per second (cps) to activity of large area surface and volume Cs-137 sources are given on the map.

The minimum detectability for Cs-137 (the upper edge of level A equals 120 cps) is 0.13 μCi/m^2 for a surface source and 1.70 pCi/g for a volume source (a large volume of soil, for instance, in which Cs-137 is mixed uniformly). These conversions do not cover the complete range of source configuration possibilities in the survey area, but do provide a limited means of estimating source values. Table 2 lists conversion factors for Cs-137, Co-60, and Tl-208. Some comparison to ground-based measurements is possible. *In situ* gamma spectroscopy measurements in a portion of the floodplain area during July 1985 indicated a concentration of 5000 pCi/g of Cs-137 compared to the aerial survey result of 3100 pCi/g.[4]

The maximum activity (level N equals 100,000 to 220,000 cps) on the Cs-137 map occurs at three locations in Melton Valley: (1) 26,000 NE, 17,000 NW; (2) 28,000 NE, 17,500 NW; and (3) 29,000 NE, 19,000 NW.

These count rates represent activities from 110 to 242 μCi/m^2 and 1400 to 3080 pCi/g for large-area surface and volume sources, respectively. These source values may be too small if their spatial extent is limited. A source of 20 meters diameter would be on the order of 18 times the above-indicated values. Table 3 lists several correction factors to apply to finite area concentrations on the Cs-137, Co-60, and Tl-208 isopleth maps.

It is important to note, again, that the aerial system measures gammas from a source both before and after the aircraft arrives over the source. Thus, the implied activity is extended beyond the true boundary of the source. These concentration isopleths have not been corrected for this smearing effect.

5.3 Cobalt-60 Concentration Isopleth Map

The Co-60 isopleth map, Figure 5, shows activity in somewhat fewer areas than does the Cs-137 map. The highest level for Co-60 occurs over the High Flux Isotope Reactor (28,000 to 60,000 cps in the 1173- and 1332-keV photopeaks) where no Cs-137 was observed. The highest level over White Oak Creek approaches 28,000 cps or about 20 μCi/m^2 at the inlet to White Oak Lake.

The minimum detectable activity (MDA) for this map is 100 cps for the photopeak search algorithm (Equation 5). The value was set at 4σ of the algorithm's counting statistics, and represents 0.07 μCi/m^2 for a surface source and 0.7 pCi/g for a volume source. A comparison of the aerial results to ground-based work is quite favorable. Over a portion of the floodplain the aerial system measured 63 pCi/g of Co-60 while *in situ* measurements yield 40 pCi/g.[4]

No Co-60 activity is visible along the west tributary of White Oak Creek in Bethel Valley. The pattern of activity seen along the east tributary is the same as that for Cs-137 with a maximum of 21,000 to 46,000 cps beside the waste ponds.

5.4 Thallium-208 Concentration Isopleth Map

The presence of Tl-208, the next to the last member of the thorium chain, was not known to the aerial survey team. The previous aerial surveys, conducted in 1973, 1974, and 1980, did not show its existence if it were present. The area where Tl-208 (and implied Th-232) exists was masked by

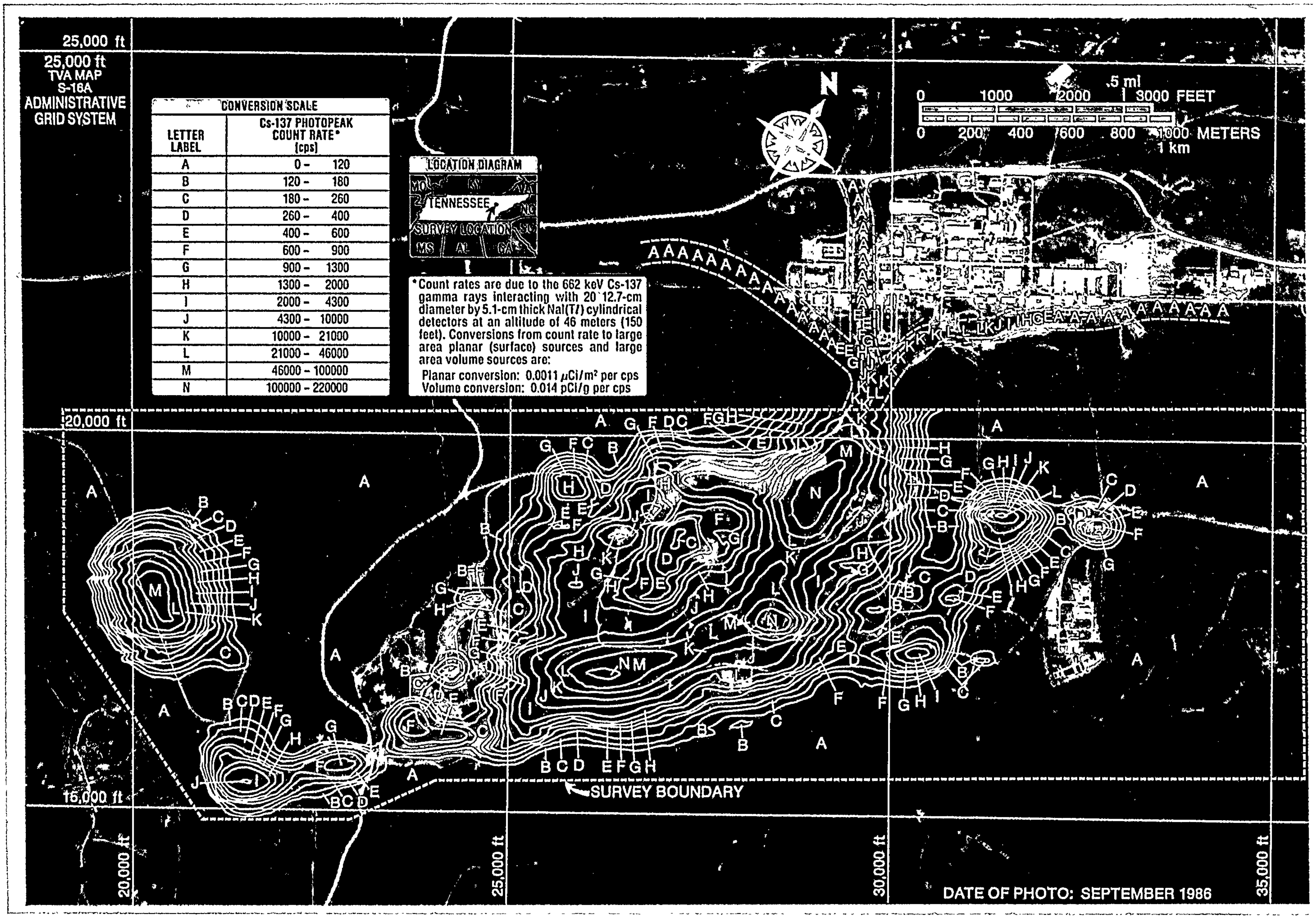

FIGURE 4. *CESIUM-137 PHOTOPEAK COUNT RATE ISOPLETHS DERIVED FROM THE SEPTEMBER-OCTOBER 1986 SURVEY OF THE WHITE OAK CREEK FLOODPLAIN, OAK RIDGE RESERVATION*

Table 2. Conversion Factors Relating Aerial Gamma Photopeak Count Rates to Radionuclide Concentrations in the Ground

	Conversion Factor[a]			
		Exponential Distributions		
Radionuclide	Point Source on Surface mCi/cps	Relaxation Depth[b] (cm)	μCi/m²/cps	pCi/g/cps
Cs-137	0.015	1000	210×10^{-3}	0.014
		10	3.4×10^{-3}	
		0.1	1.1×10^{-3}	
Co-60	0.010	1000	105×10^{-3}	0.007
		10	1.8×10^{-3}	
		0.1	0.7×10^{-3}	
Tl-208	0.036	1000	255×10^{-3}	0.016
		10	5.1×10^{-3}	
		0.1	2.2×10^{-3}	

[a] Conversion factors for 20 12.7-cm × 5.1-cm cylindrical NaI(Tl) detectors at 46 m altitude, air density of 0.00125, and soil density of 1.5 g/cm³.

[b] Relaxation depth ($1/\alpha$) is the inverse of the exponential coefficient in the soil concentration equation; $C = Co \exp(-\alpha z)$, where z is the depth. A relaxation depth of 1000 cm approximates a uniform distribution. A relaxation depth of 0.1 cm approximates a surface distribution.

Table 3. Finite Source Correction Factors[a] Versus Source Area Diameter

Diameter (meters)	Correction Factor		
	Cs-137	Co-60	Tl-208
20	18.0	25.0	27.0
50	4.5	5.1	5.5
100	1.9	2.0	2.2
200	1.1	1.2	1.3
400	1.0	1.0	1.0

[a] Multiply the source value whether in μCi/m² or pCi/g by the correction factor after converting a count rate to the source of infinite spatial extent. The error in the factor increases with gamma energy and ranges from 100% greater for a surface source to 50% less for a source uniformly distributed with depth.

the large fluence of Cs-137 and Co-60 gammas; it was discovered from perturbations in the Cs-137 and Co-60 contour maps. Subsequent inquiry has confirmed that materials from the Thorium Fuel Cycle are stored at the location shown and were present during the survey.[5]

The Tl-208 isopleth map, Figure 6, shows a maximum extent of 430 meters (1400 feet) centered near 29,000 NE, 19,000 NW on the Oak Ridge grid. The MDA represented by the upper edge of the A interval is 100 cps equals 0.22 μCi/m² for a surface layer of Tl-208. The maximum concentration from

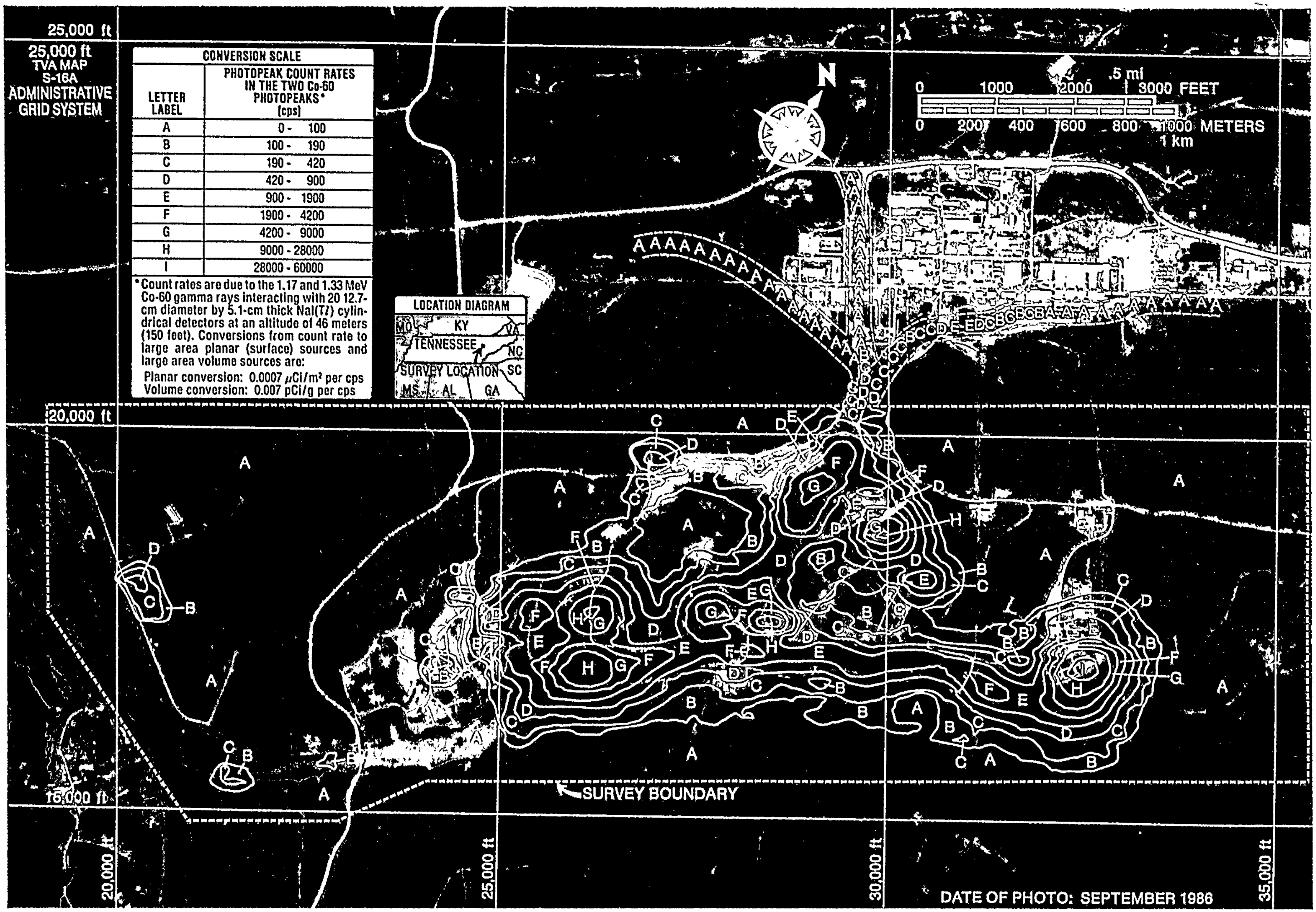

FIGURE 5. *COBALT-60 PHOTOPEAK COUNT RATE ISOPLETHS DERIVED FROM THE SEPTEMBER-OCTOBER 1986 SURVEY OF THE WHITE OAK CREEK FLOODPLAIN, OAK RIDGE RESERVATION*

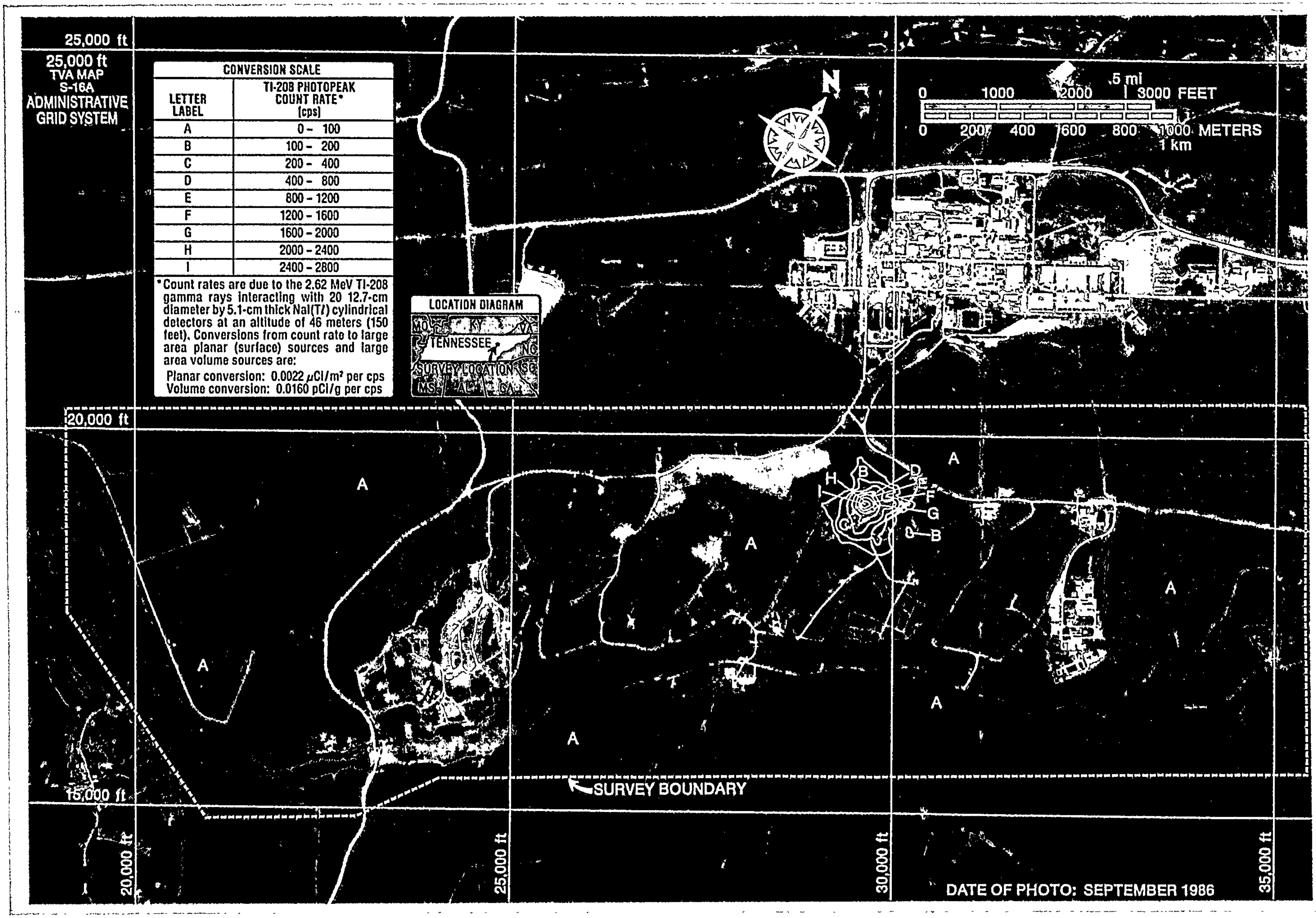

FIGURE 6. *THALLIUM-208 PHOTOPEAK COUNT RATE ISOPLETHS DERIVED FROM THE SEPTEMBER-OCTOBER 1986 SURVEY OF THE WHITE OAK CREEK FLOODPLAIN, OAK RIDGE RESERVATION*

the maximum count rate of 2400 to 2800 cps is, undoubtedly, much larger than the 5.3 to 6.2 $\mu Ci/m^2$ implied from the count rate conversion to a large-area planar source.

5.5 Gamma Energy Spectra

Representative gamma energy spectra are presented in Figures 8 through 40. The flight line segments from which each of these spectra are extracted are shown in Figure 7. The underlying photograph shows the locations.

Each spectrum is a net spectrum, except the background spectrum (Figure 26), i.e., the total in the area indicated minus a background spectrum. Background spectra were generally obtained from the easterly fraction of the survey area where no man-made activity was measurable.

6.0 SUMMARY

Although the Oak Ridge Reservation has been previously surveyed three times during the past 12 years, the current aerial gamma survey of the White Oak Creek Floodplain was more detailed. Closely spaced flight lines (37-meter separation) and data points along the flight lines at 37-meter intervals yielded a maximum data density. The lowest safe flight altitude at 46 meters provided the most sensitivity achievable to terrestrial gammas.

The intense Cs-137 fluence rates over the floodplain tended to mask the Co-60 and Tl-208 isotopes at much lower fluence rates. Indeed, some isotopes could be present, but they were not detected in the energy spectra. The isopleth plots of Cs-137, Co-60, and Tl-208 indicate boundaries of the major portion of the terrestrial man-made radioactivity to a low minimum detectable activity of about a tenth of a microcurie per square meter.

The exposure rate isopleth map provides the greatest sensitivity to terrestrial isotopes because larger count rates are involved than in the isotope plots. The object of this map is to indicate exposure rates on the ground with the understanding that topography, trees, and source configurations may cause ground-based measurements to differ markedly from the map.

FIGURE 7. *GAMMA ENERGY SPECTRA LOCATIONS*

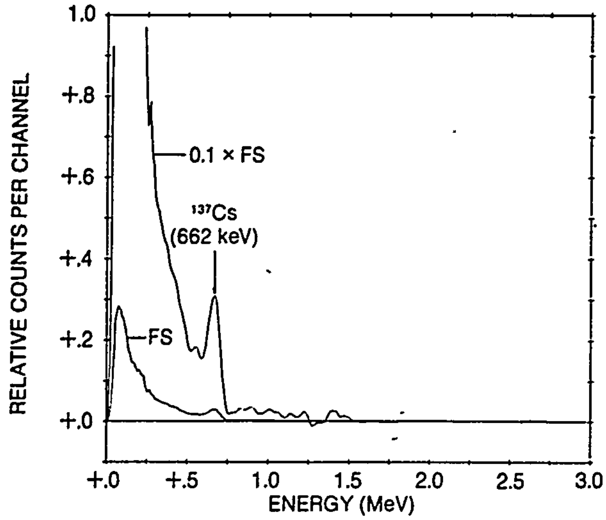

FIGURE 8. ***NET ENERGY SPECTRUM NO. 1***

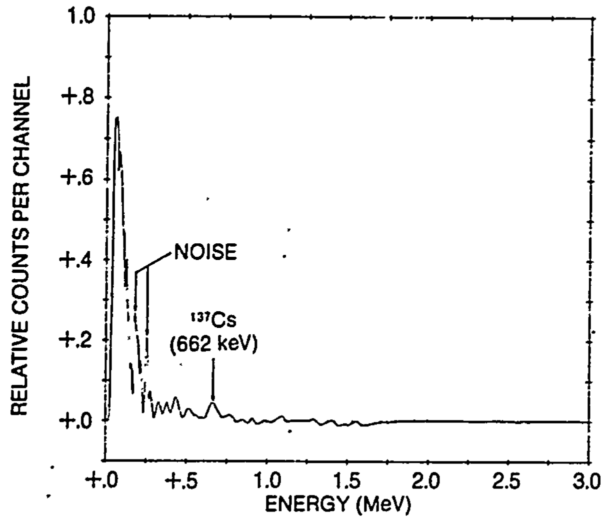

FIGURE 9. ***NET ENERGY SPECTRUM NO. 2***

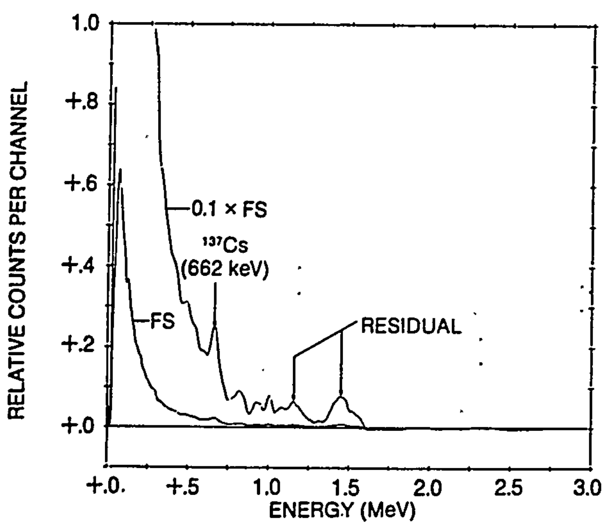

FIGURE 10. ***NET ENERGY SPECTRUM NO. 3***

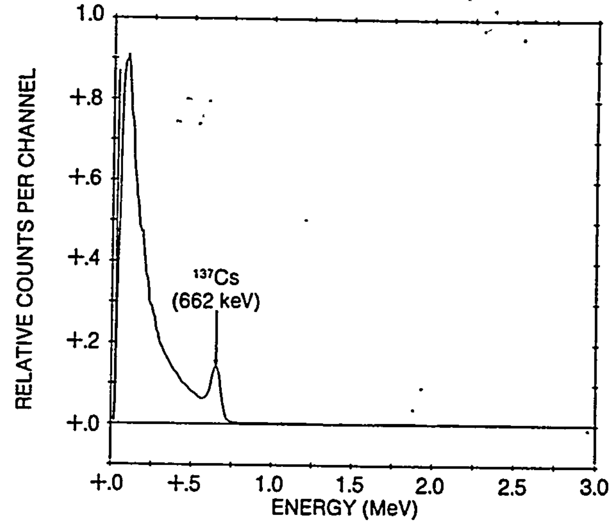

FIGURE 11. ***NET ENERGY SPECTRUM NO. 4***

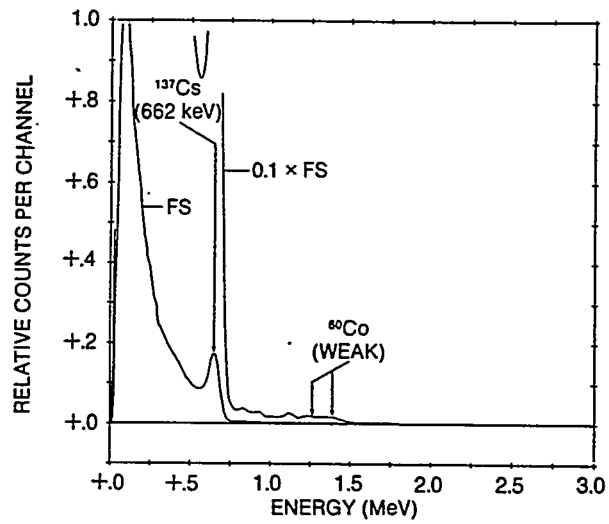

FIGURE 12. ***NET ENERGY SPECTRUM NO. 5***

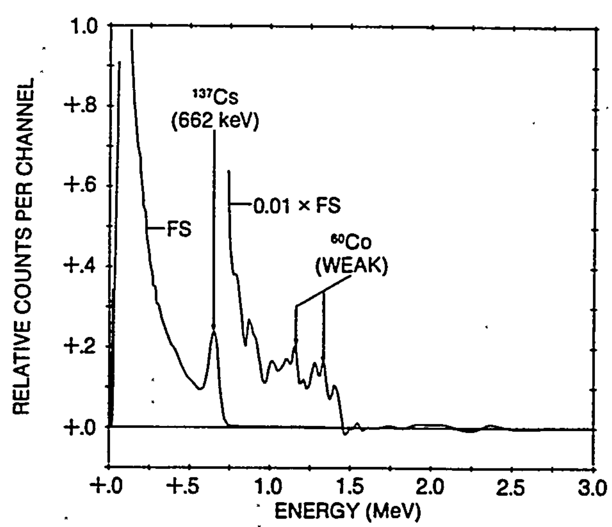

FIGURE 13. ***NET ENERGY SPECTRUM NO. 6***

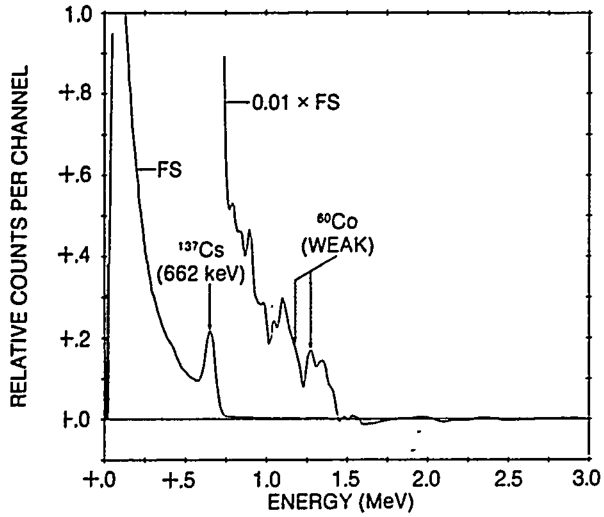

FIGURE 14. ***NET ENERGY SPECTRUM NO. 7***

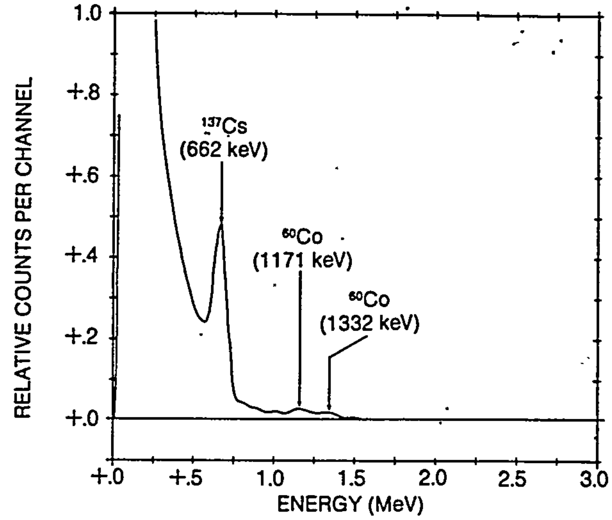

FIGURE 17. ***NET ENERGY SPECTRUM NO. 10***

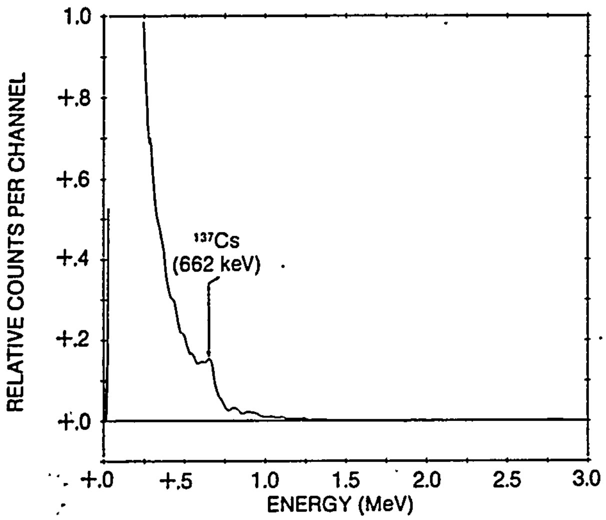

FIGURE 15. ***NET ENERGY SPECTRUM NO. 8***

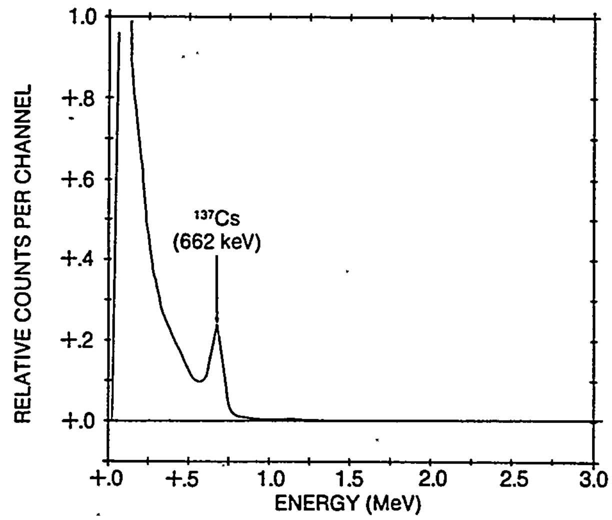

FIGURE 18. ***NET ENERGY SPECTRUM NO. 11***

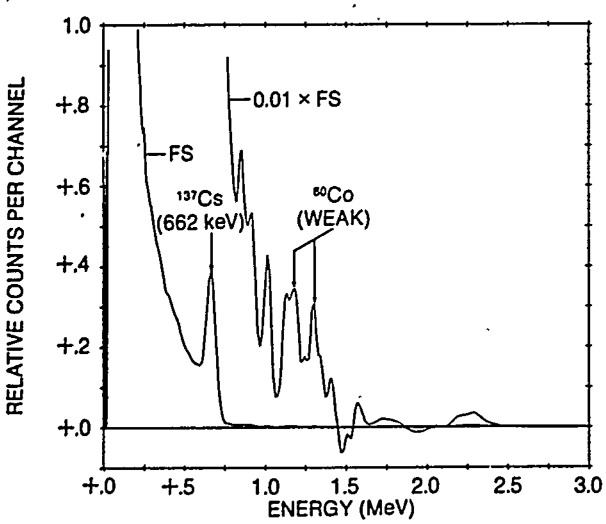

FIGURE 16. ***NET ENERGY SPECTRUM NO. 9***

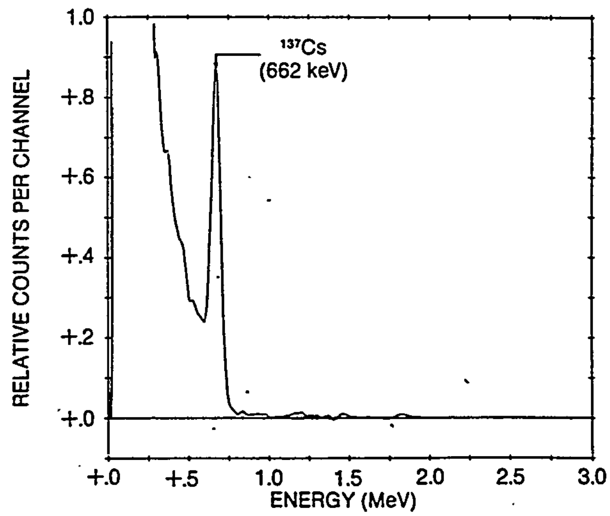

FIGURE 19. ***NET ENERGY SPECTRUM NO. 12***

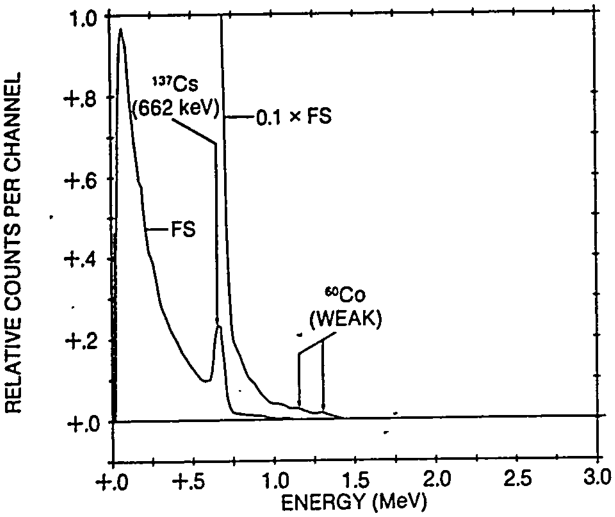

FIGURE 20. *NET ENERGY SPECTRUM NO. 13*

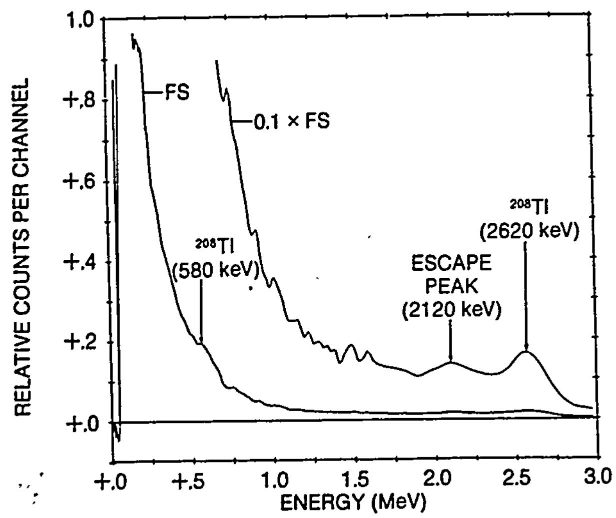

FIGURE 21. *NET ENERGY SPECTRUM NO. 14*

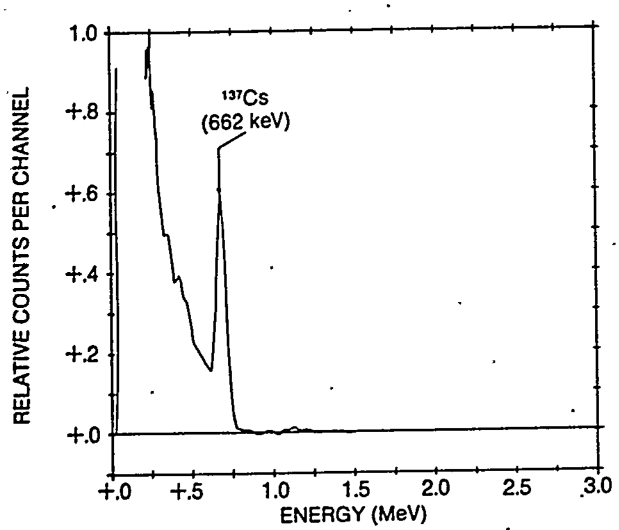

FIGURE 22. *NET ENERGY SPECTRUM NO. 15*

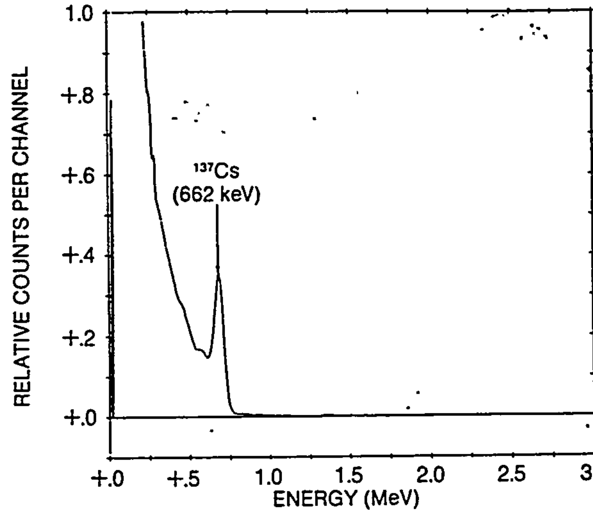

FIGURE 23. *NET ENERGY SPECTRUM NO. 16*

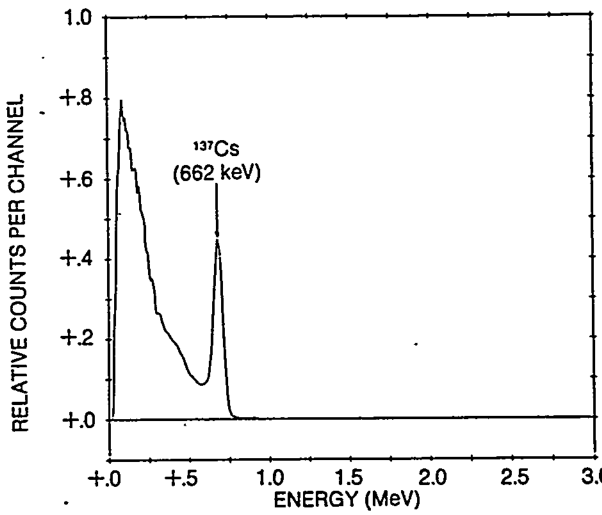

FIGURE 24. *NET ENERGY SPECTRUM NO. 17*

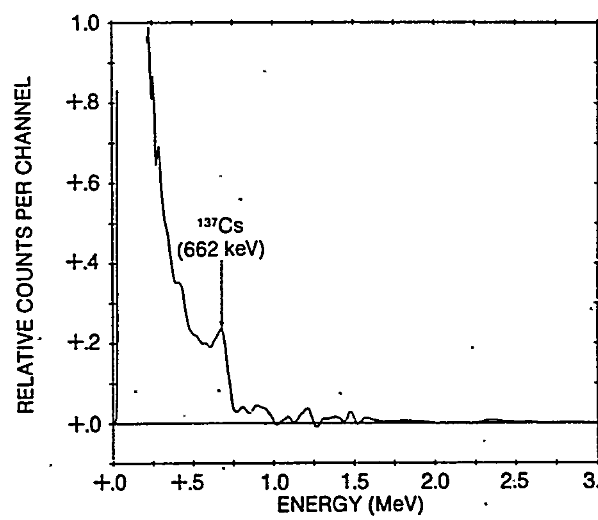

FIGURE 25. *NET ENERGY SPECTRUM NO. 18*

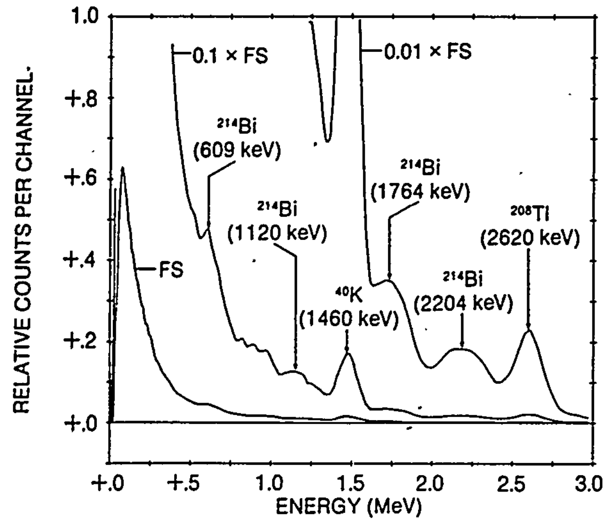

FIGURE 26. ***BACKGROUND ENERGY SPECTRUM NO. 19***

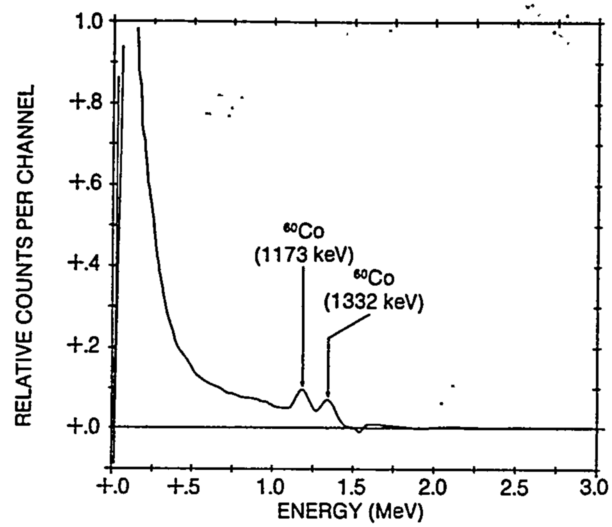

FIGURE 29. ***NET ENERGY SPECTRUM NO. 22***

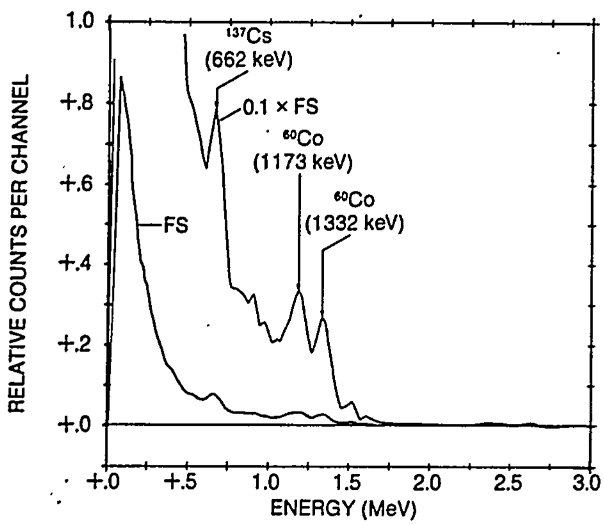

FIGURE 27. ***NET ENERGY SPECTRUM NO. 20***

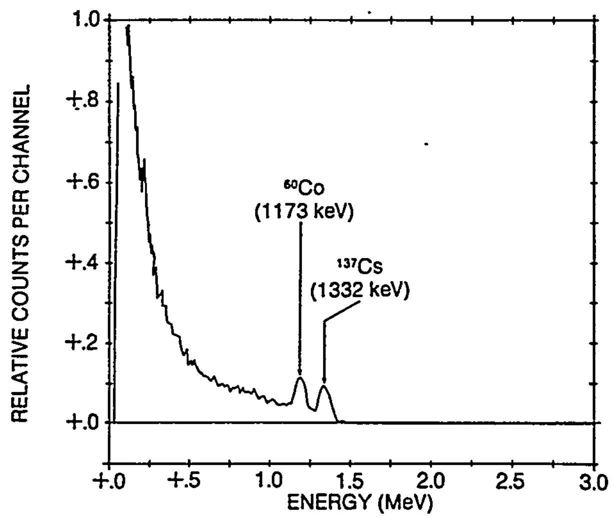

FIGURE 30. ***NET ENERGY SPECTRUM NO. 23***

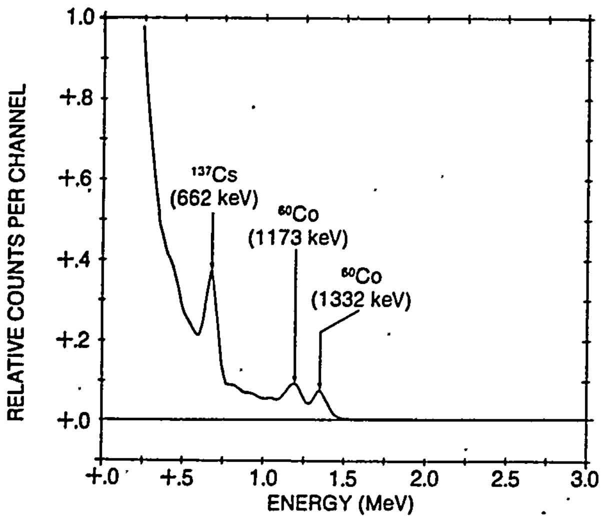

FIGURE 28. ***NET ENERGY SPECTRUM NO. 21***

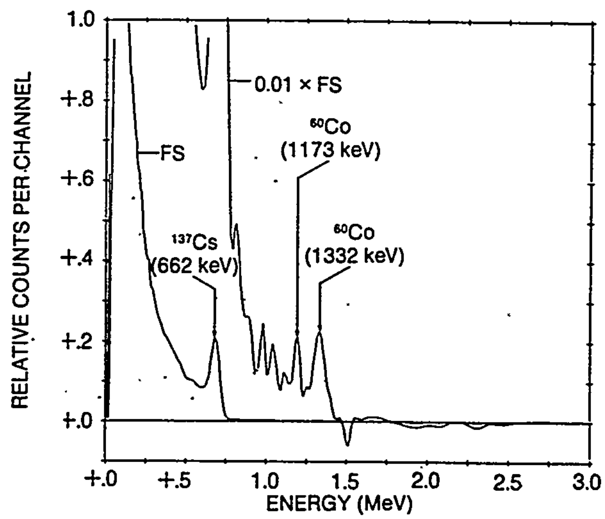

FIGURE 31. ***NET ENERGY SPECTRUM NO. 24***

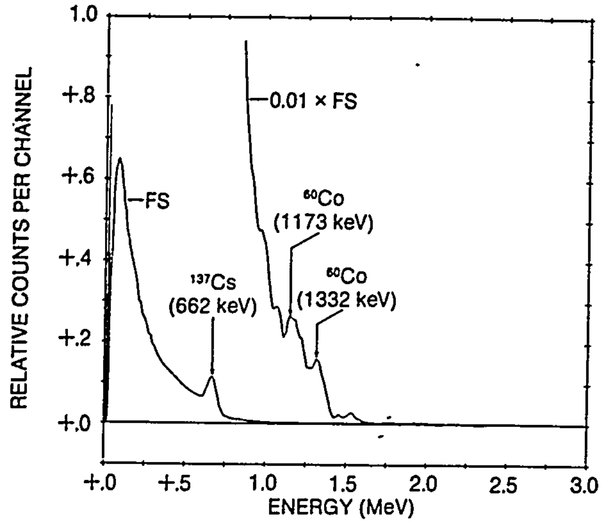

FIGURE 32. ***NET ENERGY SPECTRUM NO. 25***

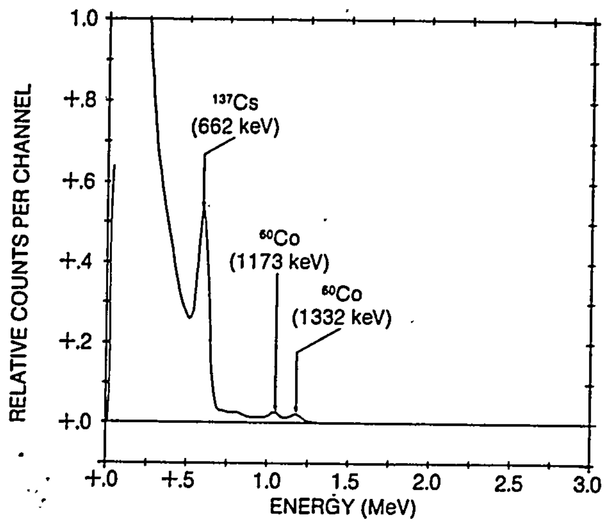

FIGURE 33. ***NET ENERGY SPECTRUM NO. 26***

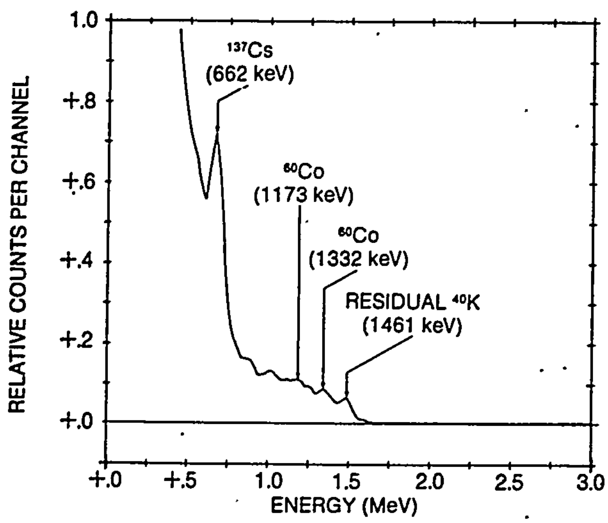

FIGURE 34. ***NET ENERGY SPECTRUM NO. 27***

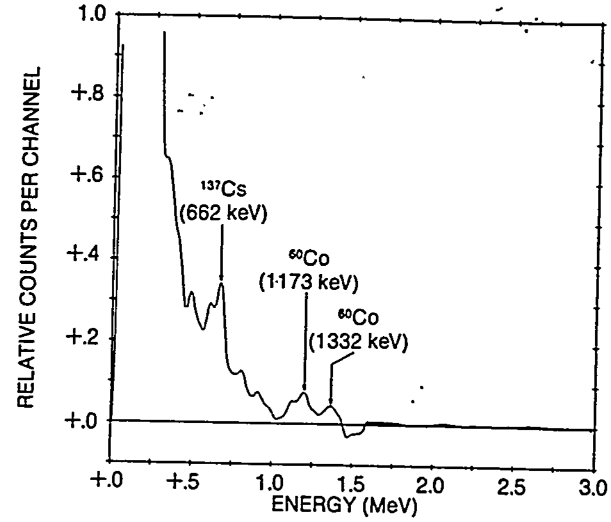

FIGURE 35. ***NET ENERGY SPECTRUM NO. 28***

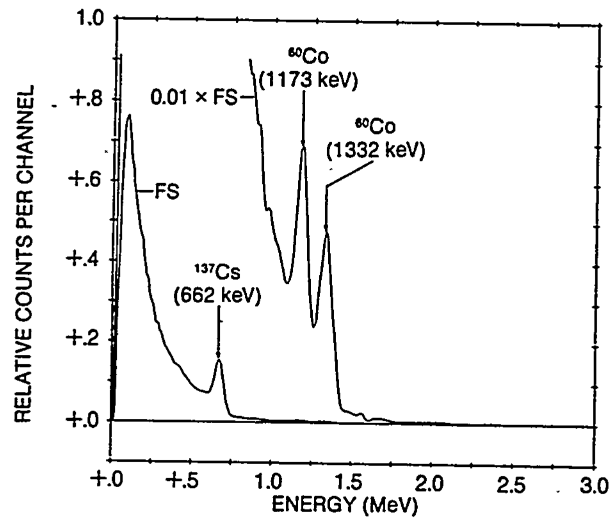

FIGURE 36. ***NET ENERGY SPECTRUM NO. 29***

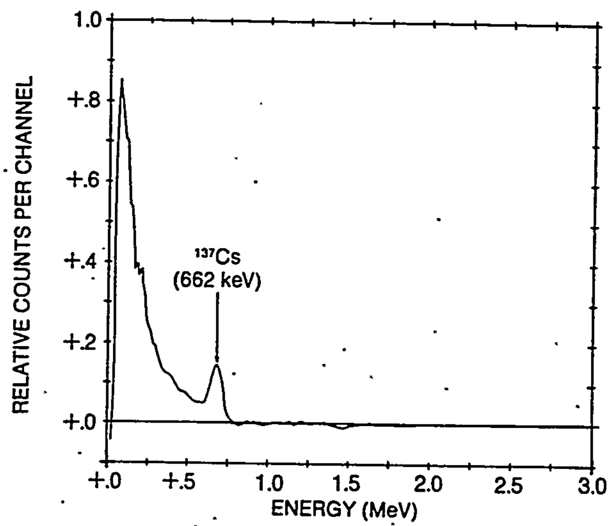

FIGURE 37. ***NET ENERGY SPECTRUM NO. 30***

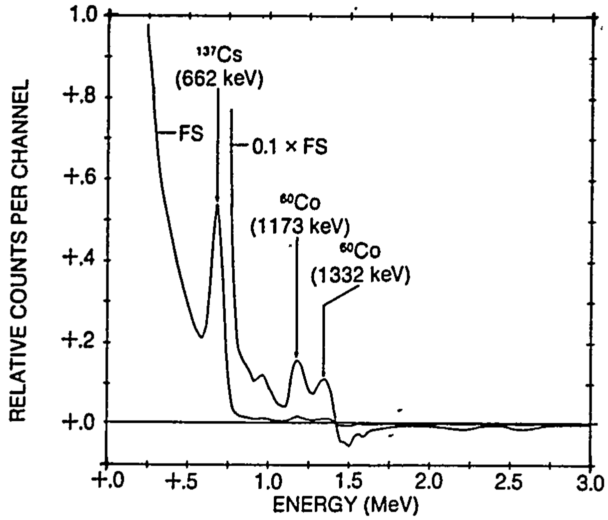

FIGURE 38. ***NET ENERGY SPECTRUM NO. 31***

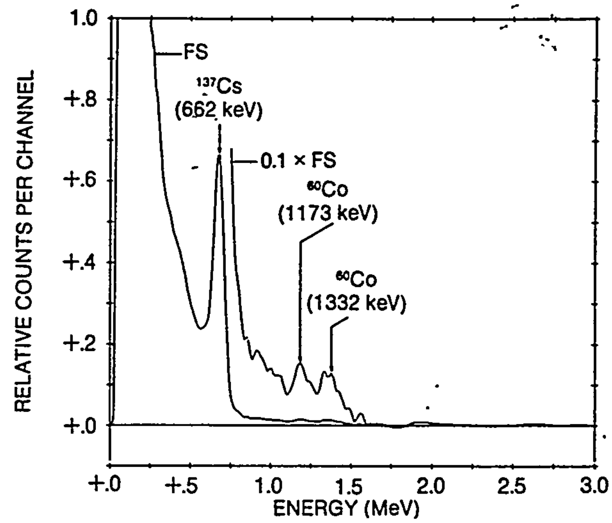

FIGURE 39. ***NET ENERGY SPECTRUM NO. 32***

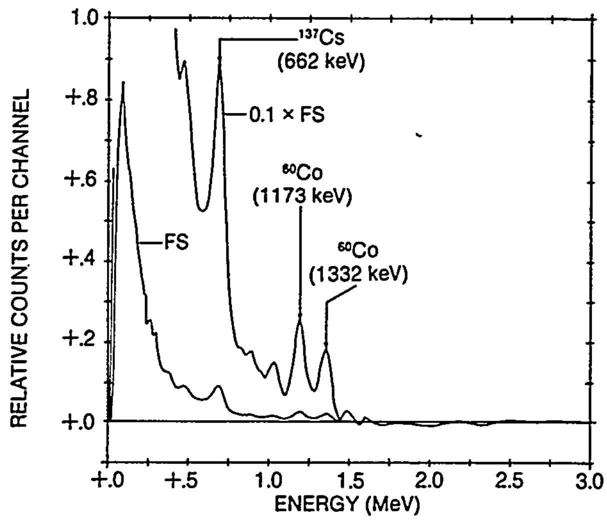

FIGURE 40. ***NET ENERGY SPECTRUM NO. 33***

APPENDIX A

SURVEY PARAMETERS

Survey Site:	White Oak Creek Floodplain, Oak Ridge Reservation
Survey Coverage:	7.4 km^2 (2.9 mi^2)
Survey Date:	30 September through 3 October 1986
Project Scientist:	A.E. Fritzsche
Date Site Photo Taken:	22 September 1986
Survey Altitude:	46 m (150 ft)
Aircraft Speed:	37 m/s (120 ft/s)
Flight Line Spacing:	30-37 m (100-120 ft)
Flight Line Length:	4.9 km (3.1 mi)
Flight Line Direction:	NE-SW
Lines Surveyed:	48
Data Acquisition System:	REDAR IV
Gamma Data Acquire Rate:	1 per second
Aircraft:	MBB BO-105
Detector Array:	Nineteen 5.1-cm thick × 12.7-cm diameter NaI(Tl) cylindrical detectors One 5.1-cm thick × 7.6-cm diameter cylindrical NaI(Tl) detector in a 2.5-cm thick lead cylindrical shield

REFERENCES

1. Burson, Z.G. February 1976. *Aerial Radiological Surveys of ERDA's Oak Ridge Facilities and Vicinity.* Report No. EGG-1183-1682. Las Vegas, NV: EG&G/EM.
2. Boyns, P.K. January 1984. *An Aerial Radiological Survey of the Oak Ridge Reservation, Oak Ridge, Tennessee.* Report No. EGG-10282-1001. Las Vegas, NV: EG&G/EM.
3. Boyns, P.K. July 1976. *The Aerial Radiological Measuring System (ARMS): Systems, Procedures and Sensitivity.* Report No. EGG-1183-1891. Las Vegas, NV: EG&G/EM.
4. Cutshall, N.H. and Larsen, I.L. 1986. "Calibration of a Portable Intrinsic Ge Gamma Ray Detector Using Point Sources and Testing for Field Applications." *Health Physics*, Vol. 51, No. 1, pp. 53-59.
5. Sherwood, C.B. June 17, 1987. Private Communications. Knoxville, TN: University of Tennessee.

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